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SATELLITE NETWORKS FOR EDUCATION

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Summary.-This paper is concerned with satellite-based educational networking. It is based on work performed in a continuing study of the potential uses of communications satellites to help meet educational needs in the United States. The paper is divided into four main sections. The first is concerned with the characteristics and structure of networks. The second section contains a discussion of pressures within the educational establishment that are providing motivation for various types of networks. This latter section also identifies studies in which networking needs for educational sectors and services are defined. Section three examines the current status of educational networking for educational radio and television, Instructional Television Fixed Services, inter- and intra-state educational communication networks, computer networks, cable-television for education, and continuing and proposed educational experiments using NASA's Applications Technology Satellites. The fourth section describes possible satellite-based educational telecommunication services and three alternatives for implementing educational satellite systems. The paper concludes with some remarks concerning public policy aspects of future educational satellite system development.

Educational Networks.-Educational networks have inherent in them a set of *connections* between widely separated locations or points, a *structure*, a *control mechanism*, and a set of *terminals* (television receivers, alphanumeric displays with provision for key-board entry of data, teletype-writers, etc.). These networks can be characterized by remote and rapid services regarding selection, acquisition, organization, storage, retrieval, processing, and transmission of information (instructional and research materials in diverse forms, data, computer programs, etc.). [1, 2] The performance objectives of the network determine the network configuration or structure, control, and terminals to be used. The environment in which the network is to be developed also has a great deal to do with the network structure and control. For example, if a network for the delivery of educational services is to be established in the U. S., the control of the network would have to be spread over a number of points. A network with a highly centralized control is not likely to be accepted in a country in which educational responsibility rests primarily with 17,000 local school districts and 50 states.

There are four distinct types of networks. [2, 3] A very common network structure is the *totally centralized structure*. In such networks, all the terminals are tied to a common node and control point. Communication can take place on a point-to-points or points-to-point basis. In certain situations, terminals can also be connected with each other *but* all such communication must be directed through the node or control point. This structure is typical of most time-sharing systems. Information networking through broadcast television stations also falls in this category. The only difference between TV broadcasting and a time-sharing configuration is that in the former case, information flows in one direction only (source to the user) and there is no provision for any real-time feedback or interaction.

Another very common network structure is a *composite-centralized network* which is an extension of the totally centralized network structure. In such structures, the control is dispersed to a number of points instead of one and the network can be thought of as an interconnection of a number

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of totally centralized networks. All constituent networks have equality of status. Control of the resultant overall network *can be equated to* standardization and compatibility requirements imposed on the *traffic* passing over the links that interconnect the nodes of the centralized networks.[2] A composite-centralized structure is the one most frequently advanced by those attempting to setup national networks such as *National Scientific and Technical Information, STINFO, and Biomedical Communication Networks*.

Sometimes, the performance objectives might require the network to be organized on a *hierarchical* basis. An hierarchical structure allows the connection between any given set of terminals to be established in more than one way which increases the reliability of the network as a whole. The interconnection is established through a hierarchy of switching terminals with control of access to the network connection by terminals of one particular rank, r , being always exercised by terminals of rank $r + 1$.

The fourth type of network structure is known as a *totally decentralized* network in which every terminal is directly connected to all other terminals in the network. It is very inefficient in its use of interconnection links. The number of interconnection links can be reduced, while maintaining the same amount of connectivity, by adding switching to the network and going to a centralized structure or a hierarchical one.

Needs and Opportunities for Educational Networking.--In education, current interest in dedicated networks, that is, those for educational purposes only, is mostly limited to those that come under centralized or composite-centralized category. Organizational considerations usually dictate that networks which are national in scope utilize a composite-centralized structure -- an interconnection of specialized and regional networks that themselves are likely to be centralized in nature. The motivation for development of educational networks comes from the advantages inherent in sharing of library, computer, laboratory, and human resources, thus making possible a more efficient utilization of the limited resources that are available to the education sector. Motivation also comes from the possibility of providing all segments of the educational community, irrespective of where they are located and their tax-base, equality of access to high-quality instructional material, resources and services; provision of educational services such as continuing education for the purposes of updating education of various segments of the adult population; services related to health and early childhood education -- in short, services that are not adequately provided by the existing educational structure.

Networking of local distribution plants, particularly those reaching homes and having large information carrying capacity such as cable-television systems, can also give economic viability to specialty-oriented programming to cater to the needs of professional groups and ethnic and cultural minorities -- something that has not been possible to date. Satellite-based networking also offers the opportunity of interconnecting and meeting the educational and informational needs of isolated populations clusters in areas where the extremes in topography and weather coupled with low-population density and small tax-base inhibit the delivery of information and education by conventional means or alternative technologies.

Currently there are several *forces* operating on the educational establishment that might lead to greater technology utilization in education. More detailed discussion of the status of and needs, trends and issues in U. S. education can be found in a paper by Morgan, et. al.[4] and a report by Anderson and Greenberg.[6] In brief, education is being asked to equalize opportunity, update itself, become more responsive to the

individual learner and the real world, and control soaring costs at the same time. In the last ten years, while enrollments were rising by some 29 percent, the costs of education have risen by 60 percent to .70 billion dollars and account for approximately 8 percent of the Gross National Product.[5] The primary approach for coping with increasing enrollments to date have been the multiplication of the number of conventional classrooms and teachers to the point where the percentage increase in educational expenditure has exceeded the growth in Gross National Product (GNP).

Current attempts to increase taxes for education have been meeting stiff opposition throughout the country. This is particularly evident in public elementary and secondary education, where the major source of revenue for operating expenses has traditionally come from local property taxes and where a "tax-payer's revolt" has forced educational planners and administrators to study ways and means of making the system more productive to maintain the quality of the service or face the necessity of providing diminished services. Education is the most labor intensive of all major U. S. economic service sectors, with one estimate being that over 74 percent of current outlays in elementary and secondary segment going to salaries for teachers and administrators.[6] Thus the "productivity" of the system is very heavily dependent upon the ability of teachers. Increasing the productivity of teachers increased allotments of monetary resources for instructional media and technology, and new instructional strategies involving optimal teacher-technology mixes seem to be key factors in current thinking at the federal level for coping with rising costs and educational deficiencies.[7]

There is also a rising demand for certain aspects of education, training, and retraining to which today's formal educational establishment has been slow to respond. According to a report, prepared for the Corporation for Public Broadcasting, there are some 30 million Americans who have no more than a grammar school education and 50 million over the age of 25 who do not have a high school diploma. These millions of Americans have available to them only the bits and pieces of a non-formal education system. The opportunity and the demand for a more flexible education system complete with training, examinations and appropriate certification or degrees are coming into focus. The demand for retraining is also growing. At the time of the report, there are over ten million unemployed and many million more underemployed. Knowledge has been growing at such a pace and the nature of job opportunities are changing so much that we can no longer expect the education or training given once to an individual during youth to be sufficient for the next thirty to forty years.

Research shows a child's future learning capacity can be significantly influenced by his or her development at the ages between three and five. There are over 14 million children in the U. S. in this age group whose educational needs are not adequately met.[8] The majority of this nation's school districts have no program for children this age and those nursery schools and kindergartens that do exist are located in the urban centers, thus not reaching large numbers of rural children. Experience in the Appalachian region has shown that television programs coupled with home-visitations can help meet this need for preschool education.

The pressures cited above appear to be stimulating increased interest in educational networking for resource sharing to reduce costs, to allow wider dissemination of and equal access to high-quality instructional materials, to reduce the software cost per child by assembling a large mass of users, to provide for new educational opportunities and to help meet educational needs that fall outside of the realm of the formal educational establishment. One may also anticipate greater reliance on telecommunications for educational planning and data collection through a network of Educational Information Systems (EIS) styled after the well known

Management Information Systems (MIS) used in corporate enterprises.

Open educational systems are being developed in many parts of the U. S. to provide more flexible education and/or to cater to the demands of those who are not reached by the existing establishment. There is considerable talk about making some of these systems technology-intensive to provide education at a time, place, and pace convenient to the student. Local telecommunications-based distribution systems such as cable-television systems are capable of bringing education directly to homes as well as specially designated and equipped learning centers. Regional or nation-wide interconnection of the individual open educational systems will allow advantage to be taken of economies of scale in providing students with a greater choice of subject and courses. These concepts are currently being examined by the National Academy of Engineering.

Further information on networking needs and opportunities for various educational sectors and services, the medical community, and libraries, can be found in the literature.[1-3, 9-13] Brown et. al.[1] have discussed networking opportunities for higher education. Singh and Morgan [9-11] have provided detailed accounts of the current status of educational television and radio stations in the United States, Instructional Television Fixed Service (ITFS) installations, national, regional, intra-state, and inter-institutional educational networks, and near-term regional and national television networking opportunities and needs; status of computer-based instruction (CBI), prospects for large centralized CBI systems, and possible satellite utilization for CBI delivery; computer utilization and communications in education, and possibilities for large, highly centralized as well as composite-centralized computer networks in education. Becker[3] and Niehaus[12] have discussed current telecommunications utilization in libraries, network needs and development, network services, and library network organization. Davis[2, 13] has discussed the plans of the Lister Hill National Center for Biomedical Communications for a biomedical communications network, services, and organization.

The U. S. Congress recognized some of the potentials of educational networking, particularly those relating to institutions of higher education, by adding Title IX, *Networks for Knowledge*, to the Higher Education Act of 1968 with provision for support of cooperative exploration of new computer and communications technologies among institutions of higher education. However, this program was never funded. Currently, the U. S. Office of Education seems to be moving in this direction as is indicated by its support of large-scale telecommunications experiments involving NASA's ATS-F satellite and a study related to the generation of "A Planning Document for the Establishment of a Nationwide Educational Telecommunication System".[14]

In an October, 1971 speech before the Convention of the National Association of Educational Broadcasters, the U. S. Commissioner of Education, Sidney P. Marland, Jr., stated, "I should like to move now, nationally, through whatever influence my office can exert, to establish educational technology as a dependable resource to be used widely and regularly - one might say routinely - to effect significant and revolutionary improvement in existing forms of education".[7] Commissioner Marland outlined the intentions of his Office to seek broadened legislative authority to support newly developed telecommunications technologies, including satellites, cable TV and ITFS.

Current Status of Educational Networking.-Educational radio and television represent early attempts at educational networking. In recent years, an organizational and networking base has developed for these services which is national in scope. Currently there are some 500 educational radio stations operating in the U. S. Only 101 of these stations meet the

necessary transmitter power, minimum staff, and operational requirements to qualify for assistance from the Corporation for Public Broadcasting (CPB) as affiliates of National Public Radio (NPR). NPR has recently initiated an interconnection of its affiliates using AT & T facilities, and a program library service. Currently NPR networking is based on low-fidelity audio channels (3-5 kHz) due to unavailability and/or high cost of high-fidelity, long-distance audio circuits. In the long-term, NPR is looking forward to establish a network capable of handling high-fidelity stereo signals to permit real-time distribution of such programs and to eliminate the trucking of tapes that is employed today.

Currently there are some 219 ETV stations in the nation. These stations are predominantly located in densely populated areas and radiate signals that are within the reach of over 75 percent of the nation's population. Of these stations, some 43 percent are licensed to state and local educational systems, 32 percent to universities and colleges and the remainder to community organizations. Stations licensed to local education boards are primarily involved with instructional programming whereas those licensed to community groups and universities are more oriented towards public television programming. Stations licensed to state agencies have, in most cases, a well balanced program schedule.

All ETV stations are affiliated with Public Broadcasting Service (PBS) which is a user controlled distribution system. PBS has been able to negotiate dedicated 24-hour networking arrangement with AT & T which, when completed at the end of 1972 will interconnect some 110 feed points and allow program origination from a number of points (see Figure 1). 105 other stations are to be served by state systems paid by those states and those in Alaska, Hawaii, Guam and Puerto Rico will be served by video tape distribution.

In addition to PBS, which is national in scope, the nation's ETV stations are also served by six regional networks: Eastern Educational Television Network (EETN), Southern Educational Communications Association (SECA), Central Educational Network (CEN), Midwestern Educational Network (MEN), Rocky Mountain Public Broadcasting Network (RMPBN), and Western Educational Network (WEN). [9] Distribution within these networks is accomplished by a combination of private microwave, common carrier and bicycling of video tapes. In addition to these regional networks, ETV stations are also served by a number of program libraries: National Instructional Television (NIT) and Great Plains National Instructional Television Library (GPNITL) for instructional programming; Public Television Library (PTL) and National Educational Television (NET) for programming that is public affairs, cultural and entertainment oriented. Distribution of programs from these libraries is based on trucking of video tapes.

At least 15 of the states in the nation have their ETV stations completely interconnected and 6 states are reported to be moving towards this goal. [9] Of the 15 states with complete interconnection, nine own the interconnection system and the remaining six use either common carrier or private facilities. Figure 1 shows the PBS, regional and intra-state educational communication networks. It also includes a number of instructional networks such as Michigan Expanded Resource for Graduate Education (MERGE) in Michigan, TAGER in Texas, Stanford system, and several others. [9] At the time of the writing of this paper, the authors have learned that an extensive instructional network has gone into operation in the state of Minnesota. According to a PBS survey conducted in late 1970, state ETV networks in several states (particularly those in Indiana, Kentucky, Mississippi, New York, North Carolina, and South Carolina) also link many universities and colleges, schools, and hospitals. [9] Total capital investment in owned interconnection facilities is estimated to be in excess of \$10 million. A similar amount of money is also paid on an annual basis

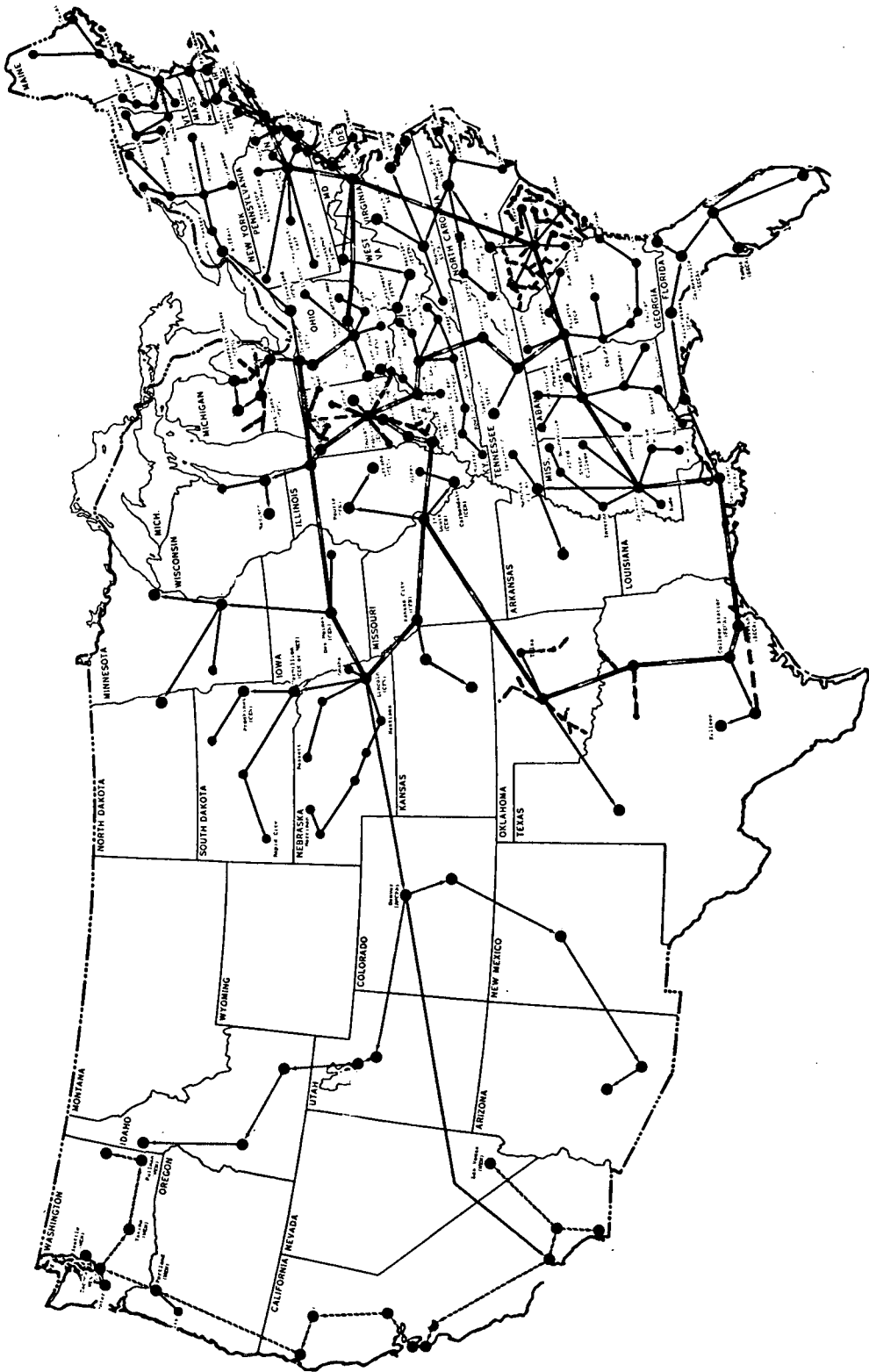


Figure 1. Inter- and Intra-State Educational Communication Networks (Refs. 9, 34)

to common carriers for leased interconnection facilities.

In addition to educational radio and television broadcast stations and associated networks, educators have also invested in Instructional Television Fixed Service (ITFS) and Closed-Circuit Television facilities. ITFS is a radio service operating in the 2500-2690 MHz frequency band and is designed for linking closed-circuit installations in schools and universities separated by wide distances.[9] As of September, 1970, there were some 160 ITFS transmitters licensed to various educational institutions/organizations in the country totalling over 560 channels. Some 32.5 percent of these transmitters are licensed to religious organizations for use in parochial schools.

According to the latest available statistics,[9, 15] use of closed-circuit television systems in education has grown considerably in the last five years. The majority of large sophisticated systems belong to institutions of higher learning whereas schools are reported to have rather simple setups. Some 26 percent of the nations schools (21,000 out of 81,000) own Video Tape Recorders.[15]

Computers have gained fairly good acceptance in education for a variety of applications ranging from administrative data processing to interactive problem solving, research, instruction and information retrieval.[10, 11] It also appears that computer utilization in education will continue to grow in terms of institutions having access to computers, time available to individual students, and variety of applications. The growth rate will be a function of a number of factors including developments in computer technology which bring about reduction in computation cost, the money supply, and the emphasis on providing equitable access to all students irrespective of where they are located and in which institution they are enrolled. "Super-computers" such as CDC STAR and Illiac IV hold special promise for educational users in the coming decade. Remote computing networks based on super-computers not only promise economies of scale and specialization but also are capable of providing a large choice of languages and systems that no ordinary institution could afford in a campus facility. The future of remote computing networks is definitely bright in situations where the basic need is the delivery of raw computing power (a great deal of power but relatively few applications on an occasional basis) and not enough to justify dedicated campus facilities.

The development of distributed (composite-centralized) networks is also foreseen in which campus or regional computing centers would be connected among themselves. Interconnection of computing centers will offer network members access to all specialized facilities--both hardware and software--located throughout the network. Another approach to computer network development may involve small, local computers for most needs, but with the capability of tying-in with larger, remote computers when required. This involves a blend of several features--minicomputers, super-computers, time-sharing, remote batch, and communications--and, in the future, may well become a common way of organizing and distributing computing power. Such an approach not only promises access to specialized hardware and software that may be prohibitive to develop at each individual location but also provides for the possibility of sharing the load with the remote computer during peak hours.

Although computer networking is still in its infancy and the differences in type, size, speed, word length, operating systems, etc. among campus computing facilities pose serious problems for distributed (composite-centralized) networks, various starts have been made in this direction. The Regional Computing Facility in the State University of New York and Triangle Universities Computation Center in North Carolina are good examples of centralized networks whereas the ARPA network and the Princeton-Carnegie Mellon-IBM network mark the beginning of distributed networks.[11]

Advanced Research Projects Agency (ARPA) experimental computer network interconnects 20 autonomous, independent computer systems to permit interactive resource sharing between any pair of systems--sharing of programs, load, data, and specialized hardware features. At the time of the writing of this paper, there is a great deal of talk about enlarging the scope and membership of the ARPA network under National Science Foundation sponsorship. Although at this time it is difficult to make accurate predictions about the rate of growth in computer networking, it is possible that in future years we will see the inception of a number of networks which will provide a competitive alternative to autonomous campus facilities and/or minicomputers.

Cable-television systems have also caught the imagination of the educational community and are likely to be of major use in urban and suburban areas for interconnection of educational institutions in communities as well as delivery of various educational services to homes and learning centers. The FCC has made it mandatory for CATV systems to carry local ETV broadcast signals and, in the top 100 markets, to provide one free channel each for instructional, local-government and public-access purposes.[16] It has also required new CATV systems to build two-way capability. Such capability is very likely to promote new interactive instructional services such as delivery of raw computing power to homes, learning centers, and schools from a centralized source, "talk-back" television providing interaction with a studio teacher, and computer-assisted instruction (CAI). A number of interactive television and data-file based inquiry systems have already been developed and many more are under development.[17]

MITRE Corporation has already demonstrated a computer controlled interactive television system (TICCIT) which seems to have great potential for instruction, consumer inquiry, etc.[18] With an estimated ultimate penetration of 40 to 45 percent of TV households in the nation, CATV has all the potentials of being a major vehicle for local educational networking and delivery of instruction. With CATV franchises under local control, it is always possible to obtain concessions in excess of those made mandatory by FCC. In fact, some instances in New York and California have been reported where organized educational interests have been able to get free drop points in schools, colleges, libraries, use of the cable operator's studio facilities, and promise for future hookup with ITFS systems and CATV systems of adjacent towns.[9]

As far as satellites are concerned, there have already been a number of experiments using NASA's Applications Technology Satellites. Table 1 lists experiments which have been completed, those which are continuing and experiments that are pending. ATS-1 and ATS-3 satellites have been and are being used experimentally for delivery of educational radio programs to Alaska, lecture, seminar, and data exchange between Stanford University and Brazil, tele-diagnosis and tele-consultation services for remote parts of Alaska, and delivery of Computer-Assisted Instruction to an Indian reservation school in New Mexico.[19] The Department of Health, Education, and Welfare together with the Corporation for Public Broadcasting (CPB) is planning a major satellite-based experiment in the Rocky Mountain states for delivery of instructional and public programming and medical service to small earth-stations located in isolated areas, using NASA's ATS-F satellite. This experiment, scheduled for the fall of 1973, will also involve Alaska and Appalachia.

Educational Satellite Networks

Introduction.--There are three distinct ways in which satellite networks for education might be developed. One alternative would be to obtain necessary channel capacity at full-cost, reduced-cost, or no-cost terms from

TABLE 1

APPLICATIONS TECHNOLOGY SATELLITES EDUCATIONAL COMMUNICATIONS EXPERIMENTS

<u>Completed:</u>	<u>Concluded</u>	<u>Spacecraft</u>	<u>Purpose</u>
Corporation for Public Broadcasting	March 1970	ATS 1, 3	Transcontinental Interconnection
<u>Continuing:</u>	<u>Started</u>		
State of Alaska	June 1970	ATS-1	Educational Radio
University of Hawaii	March 1971	ATS-1	Pacific Interconnection
Stanford University/Brazil	April 1971	ATS-3	Lecture, Seminar, Data Exchange
NPR/Alaska	Spring 1971	ATS-1	Educational Radio
NLM/OE/Alaska	Summer 1971	ATS-1	Medical/Public Education Communications
Stanford University	Summer 1971	ATS-3	CAI Delivery
<u>Approved:</u>	<u>Estimated Start</u>		
NASA/CPB/HEW	Fall 1973	ATS-F	ETV Distribution
NASA/India	Summer 1974	ATS-F	ITV Broadcast
<u>Pending:</u>			
NEA and Alaska, California, Florida and Illinois Departments of Education	1975	ATS-G	ETV/ITV Broadcast

the commercial satellite systems that are likely to come into existence shortly. An educational network could be built using commercial earth-terminals where convenient as well as those constructed specifically to serve the needs of the educational community. The second approach would be to construct a dedicated educational satellite system by deploying a relatively high-power satellite capable of serving a large number of nodes directly. Such a system could connect earth-terminals with operating centers and/or redistribution points without making use of any terrestrial microwave-relay "tails". Yet a third alternative would be to base the educational satellite system on a combination of commercial as well as dedicated satellites. Commercial satellites would be used to interconnect and feed redistribution points of common interest, such as CATV headends, while dedicated educational satellites would serve redistribution points and areas not likely to be served by commercial operators.

Table 2 summarizes possible future roles for communications satellites in the delivery of educational media and services. These roles are based upon present and near-term state-of-the-art of satellite technology and are compiled from detailed studies reported elsewhere.[4, 5]

Proposed Commercial Domestic Systems.—The Federal Communications Commission, in its Report and Order in Docket 16495 in the matter of domestic communication satellite facilities, adopted on March 20, 1970, declared that applicants proposing multipurpose domestic communications satellite systems should discuss the terms and conditions under which satellite services would be made available for data and computer usage in meeting the instructional, educational, and administrative requirements of educational institutions. The FCC further stated that applicants seeking authorization for domestic communications satellite systems should define the terms and conditions under which satellite channels would be made available for non-commercial broadcast networks, if the applicants' proposed service includes commercial television or radio program transmission. Of eight applications that were filed, four responded to the FCC directives by spelling out their public service offerings. Others either did not make any proposals or merely indicated they would be willing to accommodate requirements of non-commercial ETV networks if and when the FCC decides that it is in the public interest for ETV networks to be provided satellite channels free of charge or at reduced rates. Table 3 shows the various offerings made by commercial satellite system applicants.

We have examined the domestic satellite proposals in detail in connection with the opportunities they provide for educational networking.[4] In general, there are three major deficiencies associated with these proposals as far as educational networking is concerned: (1) low-power transponders necessitating use of costly earth-terminals; (2) use of 4 and 6 GHz frequency bands which severely restrict the colocation of the earth-terminals with urban operation and/or redistribution centers; and (3) relatively few receive/transmit earth-stations are planned which complicates the problem of access.

Due to relatively low EIRP transmissions contemplated in most of the proposals, the earth-terminals are expensive--ranging from \$6.4 million for each of the five terminals in the AT & T-Comsat proposal to \$0.1 million for receive-only terminals proposed in the Hughes Aircraft application for CATV interconnection. With the sole exception of Fairchild's plan for an optional 2.5 GHz transponder, all of the television distribution services are of the *indirect* type, i.e., programs are relayed to earth-stations that are not collocated with the ultimate dissemination points (CATV headends, broadcast stations, institutional headends, etc.) and therefore require terrestrial links for the purposes of redistribution. In 4/6 GHz operation, colocation is not always possible even if it is intended,

TABLE 2

PRIMARY ROLES FOR SATELLITES TOWARDS THE DELIVERY OF
CERTAIN EDUCATIONAL COMMUNICATIONS MEDIA AND SERVICES

SERVICE	PRIMARY ROLES FOR SATELLITES
Instructional Television	Direct delivery to schools and learning centers, to broadcast stations, ITFS and cable headends for further redistribution.
Computer-Assisted Instruction	Delivery of CAI to small, remote institutions, particularly those 70-80 miles or more away from a major metropolitan area.
<u>Computing Resources</u>	
Multi-Access Interactive Computing	Delivery of interactive computing to remote institutions for the purposes of problem solving and implementation of regional EIS.
Remote Batch Processing	Delivery of raw computing power to small, remote institutions for instructional computing and administrative data processing.
Computer Interconnection	Interconnection of the computer facilities of institutions of higher education and regional computer networks for resource sharing.
<u>Information Resource Sharing</u>	
Interlibrary Communication	Interconnection of major libraries for bibliographic search and interlibrary loans, etc.
Automated Remote Information Retrieval	Interconnection of institutional and/or CATV headends with major information storage centers.
Teleconferencing	Interconnection of educational institutions for information exchange without physical movement of the participants and for gaining access to specialists.

TABLE 3

PUBLIC SERVICE OFFERINGS OF SATELLITE APPLICANTS [Refs. 4,5]

Applicant	Public Service Offering(s)
American Telephone and Telegraph Company and Communications Satellite Corporation	Willing to discuss with Corporation for Public Broadcasting terms and conditions. Applicant referred to negotiations that were being carried out between the CPB and AT&T for a reduced rate network arrangement using terrestrial facilities for nationwide public television distribution.
Communications Satellite Corporation	Willing to work out some sort of preferential service to meet the requirements of the Corporation for Public Broadcasting.
Fairchild Industries	(1) Two fully non-interruptible satellite transponder channels, at no cost, for the Public Broadcasting Service; shared use of narrow-beam channels for "off-shore" locations of Alaska, Hawaii, Puerto Rico, and Panama Canal zone; (2) Part-time, free use of two satellite transponder channels for health-care delivery throughout U.S.; (3) Free provision of one or two instructional television channels from the satellite directly to low-cost terminals for school or community use in 2.5 GHz band; and (4) Free use of the spacecraft segment for a communications system for Alaska.
MCI-Lockheed Satellite Corporation	Proposes to make available for educational experimentation the equivalent of five TV channels without charge for a period of five years. Also plans to offer equal transmission capacity for the remaining satellite life at an undesignated fraction of the regularly established rates.
Hughes Aircraft Company	Two TV channels on the first satellite with complete back-up and no pre-emption. Two additional channels on the second satellite but pre-emptible. Free access to channels from any authorized ground station.
RCA Global Communications/ RCA Alaska Communications	Two TV channels at reduced rates for ETV distribution. Public Radio program distribution on "piggy back" basis on channels assigned to ETV. Promotional rates for experimental ITV services via standby satellite. Two TV channels for Alaska on regular rate basis.
Western Union Telegraph Company	Willing to offer one or more channels for ETV distribution if the FCC decides that it is in the public interest that non-commercial ETV networks should be provided channels without charge.
Western Telecommunications	Willing to offer no-cost or reduced cost channels for PTV networking.

particularly in urban centers that have a high concentration of terrestrial microwave links operating in the same bands on a shared basis.

The other problem or limitation of the domestic satellite system proposals is that of access to receive/transmit earth-terminals for two-way communication. In the domestic proposals, relatively few receive/transmit type earth stations are planned and two-way traffic flow is primarily point-to-point (single-route) among a few large communication centers. Access for non-TV communications is to be primarily through the established carriers (e.g. AT & T) and associated local subscriber plant. Such an approach does not make full use of the possibilities inherent in the technology for cost reductions that are obtainable from direct interconnection of certain user facilities and bypassing the local plant. In addition, domestic satellite proposals, as currently structured, do not facilitate thin-route communications such as those required for the delivery of CAI and other interactive educational material and medical services to isolated areas.

The importance of providing for some local inputs and control has been mentioned previously. In public television and radio, unlike commercial broadcasting network practices, there is a great deal of emphasis on multiple point origination, sub-national program distribution provisions or regional split, and channels for program assembly from distant affiliates. Both the Public Broadcasting Service (PBS) and National Public Radio (NPR) have agreed upon a common list of 28 origination points.[20] Future PBS networking requirements are also different from those of commercial TV networks in that they specify stereo audio and a dual grade of service--a very high performance link for program distribution to broadcast stations and an adequate but slightly lower performance link for school roof-top and CATV installations. NPR requirements or expectations differ from those of their commercial counterparts in that NPR is trying to build a high-fidelity stereo network--something that does not exist today primarily because of the cost and inadequacy of the AT & T plant.

In view of the free transponder offers by three companies, Fairchild, MCI-Lockheed, and Hughes Aircraft, it is conceivable that public television might be permitted to build additional access points, i.e., receive/transmit terminals to satisfy its multiple origination requirements. However, in view of the cost of the receive/transmit terminals capable of operating in conjunction with the proposed low-power satellites--a cost that is likely to exceed \$200,000 per terminal for even the simplest installations, the wisdom of such an investment is questionable and particularly so when the access is not to be obtained on a full-time basis and when other alternatives are available.

The limitations of the proposed domestic systems become apparent when one considers educational services other than public television and radio. Control of education in the nation is highly decentralized. Although many opportunities may exist for a nationwide ITV program distribution (or other service centers), there is also need for sub-national or regional distribution arrangements which are more flexible than those offered in most of the proposed systems. There are a large number of points (broadcast stations, institutions, cable headends, etc.) that are potential nodes in an educational network. Satellite system applicants have paid a great deal of attention to public broadcasting and relatively little to delivery of services for in-school or home instruction. Although the FCC clearly asked multipurpose system applicants to discuss terms and conditions under which satellite services would be made available for data and computer usage in meeting instructional and administrative requirements of educational institutions, only one applicant (MCI-Lockheed) attempted to respond to the FCC directive in these areas.

Although the domestic satellite systems offer some opportunities for

educational utilization, they appear to suffer from a variety of deficiencies as far as optimal utilization for educational networking is concerned. Here, as in the cases of broadcast television and cable television, development of commercial interests have overshadowed public service and educational considerations.

Dedicated Educational Satellite System.-A large-scale network involving a satellite and dedicated solely to education is a second alternative for satellite networks for education. High-power satellites, whether they be of the fixed- or broadcast-type, operating in frequency bands that allow easy colocation offer the potential of directly interconnecting low-cost, small earth terminals. These satellites open up avenues for significant cost reductions as well as introduction of many new services that cannot be implemented with low-power satellites operating in standard 4, 6 and 7 GHz bands with their rather strict frequency sharing and earth-terminal site coordination requirements.[4, 21] Use of satellites in educational telecommunications is not going to be primarily for the sake of using satellites but only if they offer significant cost reductions and/or new services that are not provided by existing facilities. In an environment where a large number of points are to be interconnected, high-power satellites (52-65 dBW EIRP per TV channel, depending upon frequency and earth-terminal population) offer the potentials of significant reductions in the price of voice and data services as well as "toll" TV, by being able to work with small earth-terminals placed within population centers.

In certain situations, satellites in combination with cable-television systems capable of handling limited two-way communications are likely to offer a viable, attractive alternative to many long-distance services provided by the existing telephone plant. Only small decreases in long-distance line costs are predicted for the 1970's in spite of tremendous advances in microwave and coaxial cable carrier systems because the increases in the local subscriber plant costs are expected to continue to offset the reductions in the long-haul transmission costs. High-power satellites also provide a means for direct delivery of television programming to areas where terrain or weather conditions and small and scattered populations do not make the development of conventional program distribution and/or broadcasting economically viable.

Our studies to date have pointed out that most satellite interconnection requirements will be satisfied by terminals capable of broadband reception from the satellite (multiple TV channels as well as voice and data) and narrow-band transmission to satellite. The narrow-band uplink transmissions are expected to contain user responses such as those involved in CAI interaction and opinion polling, voice-feedback to a central point, and limited user initiated links such as those for information retrieval (voice or low-speed data from the user end). Establishment of such two-way links requires the addition of a transmitter chain in the earth-terminals. Cost-studies indicate that in a situation involving a large number of earth-terminals, it is not realistic to talk about a video return link from every earth-terminal. There is not enough frequency spectrum available to sustain this kind of application. Moreover, provision of a return video-link costs too much. The earth-terminal price jumps up all the way to the \$20,000 - \$100,000 range depending upon the satellite transponder receiving antenna characteristics.

The economic viability of a dedicated educational service is dependent upon putting together a critical mass of communication traffic for the system. Preliminary cost studies conducted using a modified version of General Dynamics/Convair Communication Satellite System synthesis computer program[4, 22] indicate that it is not economically attractive to put up a dedicated system merely to satisfy the near-term program distribution

objectives of public television and radio. However, as the scope of the system is broadened to encompass various educational or instructional services and networking points other than broadcast stations, a dedicated system becomes attractive which caters to low-cost terminals capable of broadband reception and limited narrow-band uplink transmission using frequency bands that permit easy colocation and higher transmitter power on-board the satellite. Our first results have shown that sub-national beams compare favorably with a national distribution beam and that systems seem to have a rather high fixed-cost component, indicating that the total annual cost per channel decreases with an increase in the number of channels distributed because the initial high fixed-cost is distributed and amortized over the number of channels. The earth-segment cost is the dominating portion of the total system cost in a networking environment consisting of a large number of nodes and the system economics appear to favor large capacity and multiple users. Barnett and Denzau[23] have described the phased development of a system in which dedicated educational cable facilities are implemented prior to the launching of a satellite system.

For a dedicated educational satellite system, 2.5 GHz and 12 GHz allocations are being considered because they permit power-flux densities large enough to achieve optimal balance between the satellite radiated power (and hence cost) and the earth-terminal cost when the earth-terminal population is large. The recently allocated 2.500 - 2.690 MHz frequency band appears to offer the most economical operation for a variety of applications. Advantages include manageable antenna size, relatively tested hardware and low hardware costs, low atmospheric and rain attenuation, and relatively efficient DC to RF power conversion. However, this band is only 190 MHz wide and it is speculated that the total 190 MHz bandwidth may never be used in North America due to requirements for radioastronomy instruments that operate above 2670 MHz. In addition, 35-MHz wide chunks of this band, on both ends, are also allocated to the fixed satellite service for small earth-terminal demand-assigned communications. Thus, it is likely that only 120-155 MHz of spectrum will be available to educators, enabling distribution of some 4-5 TV channels or equivalent in a particular geographic area. By employing cross-polarization and RF carrier staggering, the number of channels could be doubled.

It is not inconceivable at some later date, that demands for educational communication might exceed the information carrying capacity offered by the 2.5 GHz band. In this case, our studies[24] have suggested that the 11.7-12.2 GHz band may be used for accommodating additional educational services. The 2.5 GHz band is definitely superior to the 12 GHz band for handling interactive as well as multideestination data links, and it is suggested that interactive communication services be given preference over TV and radio program distribution in 2.5 GHz band. In order to accomplish this in the main 48 states, it will be necessary to remove any service restrictions on the 2.50 - 2.69 GHz band for educational telecommunications during national rulemaking proceedings. Retention of the "Broadcasting Satellite Service" limitation imposed by the 1971 World Administrative Radio Conference inhibits the potentials of this band for educational telecommunications. The two 35-MHz wide fixed-satellite allocations are only likely to be used in Alaska.

It is also imperative to seek a suitable uplink allocation for use in the main 48 states to go along with this downlink allocation for the purposes of establishing low-cost uplinks. A 2.5 GHz and 12 GHz combination is recommended in case the telecommunications demand exceeds the capacity of the 2.5 GHz band. In situations where a common earth-terminal must handle two different frequency bands, the colocation advantage of the 2.5 GHz band will be severely reduced in combination with any frequency band other than 12 GHz in the frequency spectrum of near-term interest.

A substantial portion of the technology needed for such a system should be available in the mid 1970's. The requirements imposed on antennas and attitude control systems are such that they can be met by current hardware development, e.g., the 30-foot ATS-F & G space deployable antennae. High power and high-efficiency TWTs and Klystron transmitters are currently undergoing tests to provide power in excess of 100 watts at 2.5 GHz and in 1-4 kW range in Ku-band with efficiencies in excess of 50 percent.[25, 26] Prime power generation in 1 to 20 kW range is feasible by extension of solar cell array technology and without resorting to more exotic alternatives, i.e., solar thermodynamic, reactor thermodynamic, and reactor thermionic techniques. The state-of-the-art of launch vehicles does not impose any restrictions. Saturn V is capable of putting a 52,000 lb. payload in the synchronous orbit. Our estimate is that a Titan *IIIC*₇ vehicle or a vehicle with lesser payload capability would suffice for the launch of educational satellites in the near-term future.

NASA and private industry - sponsored research and developmental efforts in the area of low-cost earth-terminals have already produced a number of low-cost single-channel receiver designs in the frequency bands of near-term interest and work is continuing on at least two multi-channel terminals for the 12 GHz band.[27, 28] Table 4 shows characteristics and costs of single channel receivers available within today's technology.

At Washington University, we have recognized the significance of satellite-based interconnection of today's cable-television system or tomorrow's Broadband Communications Networks (BCNs) and are currently in the process of fabricating a low-cost broadband earth-terminal capable of receiving 10-12 TV signals in the 12 GHz band to be used in conjunction with a relatively high-power satellite (52-55 dBW ERP per TV channel).[28] We have opted for a multi-carrier arrangement because it allows individual TV channels to be originated from different programming centers simultaneously and because such an arrangement permits channelization of the satellite-borne transponder design. The terminal is to use a broadband 12 GHz mixer, with approximately 6 dB noise figure and a 1.5 GHz I.F., currently under development at the Westinghouse Corporation for NASA's Goddard Space Flight Center.

The technological areas which in our opinion require new and vigorous efforts are: shaped-pattern antennae, array antennae capable of providing relatively narrow spots on earth (0.1 degree or so), and RF/IF channel switching onboard the spacecraft.

A key element to the creation of a large-scale educational satellite network lies in the search and design of an organizational and administrative structure that brings all or a sufficient mass of educational users under a single umbrella and penetrates traditional institutional, organizational and political boundaries. A study of design considerations and restraints involved in the organization and administration of an instructional satellite system[30] has put forth one possible organizational alternative in terms of a cooperative public-private sector effort in which a non-profit instructional satellite corporation controls the satellite and ground equipment and in which software is made available to schools on a competitive basis.

In the structure of the system envisioned by DuMolin and Morgan,[30] there are two independent spheres of control, (1) the administrative segment, and (2) the program-production segment. Administration is the responsibility of the non-profit corporation that has complete control over the earth-terminals, space segment, and accounting system for the purposes of billing and protection of copyright. The non-profit corporation is to function like a common carrier, providing any producer of educational media an opportunity to market his product over the system. The non-profit structure was chosen to ensure that the organization would provide services

TABLE 4
SATELLITE BROADCAST RECEIVER FRONT-END COSTS AND NOISE CHARACTERISTICS
(for production year beginning 1971)
(after Ref. 29)

Frequency	Receiver Type	Noise Figure (dB)	Unit Cost	
			Quantity 103	Quantity 106
620-790 MHz	Mixer	6.7	\$76.00	\$41.00
	with Transistor Preamp.	3.6	\$82.00	\$44.00
	with Tunnel Diode Preamp.	3.6	\$85.00	\$46.00
	with Uncooled Paramp	1.3	\$94.00	\$51.00
2.50-2.69 GHz	Mixer	7.8	\$89.00	\$44.00
	with Transistor Preamp.	5.75	\$106.00	\$52.00
	with Tunnel Diode Preamp.	4.1	\$106.00	\$52.00
	with Uncooled Paramp	2.3	\$121.00	\$60.00
11.7-12.2 GHz	Mixer	9.9	\$119.00	\$46.00
	with Tunnel Diode Preamp	6.15	\$141.00	\$54.00
	with Uncooled Paramp	5.75	\$168.00	\$65.00

to outlying and rural schools where operation might not prove sufficiently attractive to a profit-making corporation. This separation of administrative and program-production segments is similar in concept to the separation of programming and transmission operations in space broadcasting proposed by Hult[31] and is designed to provide an incentive for the development of adequate amounts of quality software as well as provide safeguards against the dangers inherent in the centralization of program production and content control. This study represents once possible organization form. Much more work remains to be done to explore this and other alternatives.

At present, there exists a variety of organizations which could play a role in helping to provide a framework for bringing both regional and national educational networks into being. For example, in the planned ATS-F educational satellite experiment, the Rocky Mountain portion is being planned by four organizations which have interests which cut across state lines, namely, The Federation of Rocky Mountain States, The Western Interstate Commission on Higher Education, The Educational Commission of the States and the Rocky Mountain Corporation for Public Broadcasting. Both the U. S. Office of Education and the Public Broadcasting Service have a national outlook. The National Instructional Television Center and the Great Plains National Instructional Television Library operate instructional tape and film distribution services which reach all parts of the country by mail. Other organizations could be mentioned.

Hybrid System.-A third alternative for the development of educational satellite systems is a combination of commercial satellite facilities and a dedicated satellite system. Commercial satellite systems are likely to be used to interconnect CATV or cable television systems to provide additional TV channels to cable system subscribers. Cable interconnection is also important for educational interests because it not only can provide local interconnection of schools in the area but a good percentage of homes as well. Cable operators are not likely to own and operate two earth-terminals, one for receiving commercial programming from one of the commercial satellites and the other for receiving educational programming from a dedicated educational satellite. However, there is no reason why an arrangement of the type proposed by Hughes Aircraft[32] for terminal ownership and fees cannot be worked out for the educational component. This alternative will be the subject of future study.

Concluding Remarks.-In this paper, we have discussed the characteristics of educational satellite networks, the rationale for establishing such networks, relevant experiments now underway, and some possible alternative forms which might develop in the future. Perhaps the most exciting prospect from the technological point of view, is that of a dedicated educational satellite system which employs a high-power satellite as part of a large scale educational telecommunications network. Such a network could provide a wide variety of educational services and media to a diverse community of educational users.

Although NASA has been developing bits and pieces that go into the making of a high-power satellite, no strong national commitment to the development, flight-testing and demonstration of the capabilities of a high-power satellite exists today. According to Feldman and Kelly[33] under Congressional direction to de-emphasize point-to-point communication satellite activity when the Communications Satellite Corporation was established, NASA essentially abandoned the development of high-power satellites and then proceeded to de-emphasize all satellite communications as well.[34] Early research and development supported by NASA and the Department of Defense created the technological base for the Intelsat series, but with

exceedingly modest further support since the early 1960's, progress in this direction has been less than satisfactory.

Lately, there has been a great deal of talk about turning American industry and technology away from defense and interplanetary travel to help seek solutions for problems here on earth. Educational satellite networks provide a potential area for such endeavors. However, we would close with the following note of caution.

There are many things right with U. S. education. Many of the wrongs will take more than technology to correct. We have no guarantee that a large-scale dedicated educational satellite network will make things better. If the technology is improperly deployed or misused, the possibility clearly exists that it might make things worse. The success or failure of such a system will depend to a large extent upon the quality and quantity of information which flows over the network, the way such information is used and the effect that such information has upon the educational user. The possibility of deploying a large-scale educational satellite system also raises a number of important educational, legal, economic and social issues which must receive careful attention before decisions are made as to whether or not to implement such a system.

Experiments with a variety of teacher technology mixes using satellites and other technology including video cassettes and cable television, should provide important new insights if they are properly done and carefully evaluated both with regards to costs and benefits. Planning for future educational satellite networks must heavily involve individuals who can assess the social, political economic and educational impact of such systems. Furthermore such efforts should be subject to early and continuing public exposure and debate. In this manner, it is hoped that form and substance of any educational satellite networks which may emerge will be such as to enhance education and equality of educational opportunity in a democratic society.

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